In Defense of Chaos:
The Chaology of Politics, Economics and Human Action

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L.K. Samuels

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Foreword

"How do you hold a moonbeam in your hand? How do you keep a wave upon the sand?" These words from *The Sound of Music* bring out the elusive nature of chaos. In life, most things cannot be captured for long. It is like trying to encapsulate time itself.

Starting from an accident in a computer software program to predict future weather, scientists in every discipline began to see something fascinating in how the chaotic systems played on the dynamic stage. They discovered hidden order in chaos and hidden chaos in order. Not long after that revelation, chaos theory as a promising new science was born.

For me, it all began back in the late 1980s. A dear friend, Dagny Sharon, made me aware of this new science, along with its socio-economic and political implications. She insisted that the mechanics of chaos theory had the possibility of completely changing the world as we knew it. And in that friendly discussion, she suggested that chaology had the potential to prove scientifically that the flexible, open-ended systems of a free society indeed work, compared to the closed, inflexible and anti-evolutionary systems often employed by governments. At the time, I simply pondered the possibilities of an obscure science.

Then along came Michael Crichton's book *Jurassic Park*, and later the movie, which encouraged me to delve deeper into theories that offered a better explanation of how both the universe and society truly operate. Soon after that, I discovered James Gleick's *Chaos: Making a New Science* and other books. I began to put words to paper around 1992 when I found myself stranded in the small desert town of Inyo-Kern, waiting for an auto mechanic shop to replace my broken transmission. I wrote for days, and so began my excursion into writing a book on a subject that almost seemed to defy description. Those early writings in the desert eventually became the first chapter of this book

The internet was of little help in the beginning, because it lacked the wealth of information required to research chaos and complexity science. But by 2007 and 2008, the internet and its resources had exploded with a cornucopia of related material. In early 2011 I sent my manuscript to two professional editors for publishing.

Although I had minored in journalism, my background did not seem to lend itself to writing a book on science, politics and economics. While the editors peppered me with questions about syntax, sources and logic, I searched for an understanding publisher. Fortunately, I found a think tank eager to be

my publisher–-Cobden Press of the Moorfield Storey Institute, founded by James Peron.Writing is a lonely endeavor, but what makes it possible is support of friends, family and colleagues.

I would like to thank a number of my cheerleaders—my wife, Jane Heider, who went through the book determined to clean up all of my grammatical indiscretions; Prof. David R. Henderson, who looked over a number of chapters, especially the one on economics, giving me many valuable suggestions; my editors Jackie Estrada from San Diego and Elizabeth Brierly from the San Jose area, and my final proofer, Linda Blumenthal.

This odyssey has led me to one major conclusion: chaology and complexity science will change the way we think. With more knowledge about the workings of this new science, humanity will be set free to consider and pursue every conceivable possibility.

1 The Beginning—Defense of Chaos and Complexity

Chaos is the law of nature; order is the dream of man.
—Henry Adams, historian

There is no detailed blueprint, only a set of laws with an inbuilt facility for making interesting things happen. The universe is free to create itself as it goes along.
—Physicist Paul Davies, *The Cosmic Blueprint* (1988)

Why do things behave the way they do? Why do planets wobble, stars fluctuate, and galaxies bend? Why is the universe speeding up instead of slowing down? Why is observable matter in the universe clustered together in galaxies instead of being evenly spread out across vast reaches of space?

Closer to home, how did simple molecules of the primordial soup produce the first cell, on a lifeless rock revolving around a thermonuclear sun? Or more fundamentally, how can evolutionary processes go against the laws of thermodynamics—a condition in which entropy demands that the universe must eventually grind down to a cold state of disorder and disorganization? And if entropy is always increasing, how can biological systems self-organize and achieve a higher order of complexity? These are just a few of the perplexities and paradoxes that have emerged from the fascinating field of chaos science: chaology.

The Origins of Chaos

For centuries, mathematicians and physicists ignored or overlooked any strange anomaly they encountered. They could hardly be blamed. They did not have powerful analytical tools to figure out why so many of their experiments resulted in erratic and inexact outcomes. They had no course of action other than to see randomness as just "white noise," like static radio signals, or to conclude that their experiments had simply gone bad. In less publicized cases, scientists would actually smooth over, or "linearize" results, to make outcome fit theory, which geologist Thomas Chrowder Chamberlin referred to as "pressing of the theory to make it fit the facts and a pressing of the facts to make them fit the theory."[1] This "confirmation bias" would start to change once the power of computers and mathematician James A. Yorke had arrived on the scene.

A professor of mathematics and physics at the University of Maryland, Yorke had read an obscure but fascinating article penned in 1963 by meteorologist Edward Lorenz. Published in the Journal of Atmospheric Sciences, Lorenz's article discussed the curious outcome from a computer program designed to chart and study weather systems. While working at Massachusetts Institute of Technology (MIT), Lorenz had built one of the first computer modeling programs to simulate weather patterns. One day in 1961, Lorenz wanted to replay one particular sequence of his model. This time he decided to cheat: he started in the middle of the sequence instead of at the beginning. When he came back to the computer, the pattern had diverged wildly and evolved into an entirely different outcome from that of the original data. Dumbfounded, Lorenz started to search for the problem. He soon discovered why. In order to save paper, he had printed his report using three decimal places, not the usual six. Instead of typing in the normal 0.506127, he had input 0.506. Little did he know that this simple mistake would eventually usher in a new science so significant that mathematician Robert Devaney would refer to this science, chaos theory, as "the third great scientific revolution of the 20th century, along with relativity and quantum mechanics."

In his research paper, Lorenz attributed the deviations to an effect in which small initial conditions may lead to large changes—sensitive dependence on initial conditions—later to be known as the "butterfly effect." And yet this consequence of chain reactions was hardly unknown to the general public. Even an English nursery rhyme from the Middle Ages alluded to the danger of little problems metastasizing into big ones, cautioning:

> *For want of a nail, the shoe was lost; for want of a shoe, the horse was lost; for want of a horse, the rider was lost; for want of the rider, the battle was lost; for want of the battle, the kingdom was lost. And all for the want of a horseshoe nail!*

A more famous example is the loss of the U.S. Space Shuttle Challenger, because of the failure of a tiny, synthetic rubber O-ring seal on the solid rocket booster.

Lorenz had discovered scientific evidence to prove that dynamic systems are sensitive to initial conditions. In more concrete terms, a butterfly flapping its wings in Tokyo could influence a hurricane in the Gulf of Mexico a month later. Effect was not proportional to cause. A ball hit twice as hard will not necessarily fly twice as fast. Naturally, this shocking revelation flew in the face of traditional linear theory, which said that motion output is directly related to input force. But there was more to come. Years later, when chaologists started to debunk linear systems, they discovered a whole array of problems that chaos theory might solve. Lorenz had been instrumental in starting a new age of inquiry, but the world would have to wait over a decade before someone rediscovered Lorenz.

Unfortunately, Lorenz's article had been published in a meteorology publication and garnered little interest. Not until Yorke found it and applied his mathematical skills did other scientists take notice. In reexamining Lorenz's computer model, Yorke discovered to his surprise that the universe is fundamentally disordered. Chaos is ubiquitous, not at all rare. In 1975 T.Y. Li and Yorke co-wrote a now-famous paper concerning one-dimensional systems, *Period Three Implies Chao*s, which showed a stable oscillating between three values. The paper jolted the physics community. It implied that "mathematical chaos" is not only stable, but possesses a sort of structure. This marked the birth of the modern chaos theory and complexity science. Yorke is now credited with giving this new science of chaos its name.

Why was this discovery so revolutionary? Why would anyone care about some mathematical equations showing chaos to be found everywhere and residing in everything? Average people in the street already knew that chaos ruled their lives. On a daily basis, people struggled with a disorderly and dysfunctional world that often defied logic. So what was the big deal?

It was a big deal to the scientific community. As science journalist James Gleick wrote in his immensely popular book, *Chaos: Making a New Science*, "Where chaos begins, classic science stops."[2] And indeed, the traditional scientific foundation had been shaken to its core. The reason was obvious: Conclusive mathematical evidence that chaos is ubiquitous meant that the entire scientific world had been based on a false premise. Immediately, this dethroned the static, mechanistic world of Isaac Newton and his era of enlightenment. The whole notion of "deterministic predictability"—of a fixed, replicable state of reality which, when called upon, obeys—was found to be completely invalid. This so-called fuzzy logic of complexity and chaos had overthrown centuries of ironclad theorems based on machine-like calculations. The universe could no longer be considered a single dimension, chock-full of straight lines or acting in the fashion of an industrial assembly line. Scientific methodology would have to be reconfigured and scientists could no longer ignore unsolved mysteries of chaotic systems.[3]

To Solve Unsolved Mysteries

But why did scientists begin to look beyond orderly systems in the first place? Actually, they had little choice. Studies, research, and experiments kept coming up with inconclusive outcomes.

One of the most famous anomalies was the mystery surrounding the orbit of planet Mercury. In 1859, an astronomer noticed that Mercury's perihelion changed slightly during each orbit. It had been assumed that the planet's strange gravitational variations were caused by an unidentified nearby body, most likely an undiscovered planet. Most astronomers believed that Mercury's unsteady patterns could not be a factor. Orbits of planets were considered immutable and regular. So astronomers solved the problem by predicting a mysterious planet to compensate for Mercury's eccentric orbital behavior. They named the planet Vulcan, but obviously, it has never been found, it was never found.

Another example: For centuries, British cartographers had mapped the coast of England, only to find one glaring inconsistency that continued to confound them and scientists. After charting smaller areas of the coastline and then adding up the numbers, they would get a total coastline measurement of over 8,000 miles. There was only one little problem: The British coastline had already been calculated to be only 5,000 miles long. To the mapmakers, it appeared that a finite coastline area of Britain was being bounded by a variant line. This phenomenon became the subject of many mathematical theories, until the introduction of the Mandelbrot set, which established the self-similarity of fractals—which is an illustrated journey into the heart of chaos.

Meanwhile, ecologists were continually baffled by extreme declines and increases in animal populations. In Alaska, Pacific salmon saw substantial declines in population during the 1920s, 1960s, and 1970s, but for some reason, they always rebounded. The reasons were never clear. Similarly, ecologists studying sea otter populations along the coasts of California and Alaska could not detect any conclusive explanation for sharp fluctuations in populations.

The mysteries kept piling up. Frustrated ornithologists could not figure out how, when swarming, birds would spontaneously fly into precise formations. Physicists experimenting with and attempting to understand fluctuations in a particle chamber repeatedly failed to predict what subatomic particles would do. Medical researchers studying heartbeat data discovered that hearts do not beat in precise intervals; surprisingly, dynamic irregularities appear normal for healthy hearts. When close measurements were taken of the swinging action of a pendulum—the very heart of a clock—unpredictability was clearly evident. After using high-speed computers to study the pendulum, scientists discovered that even the movement of the pendulum did not behave like a normal linear system. Over long periods, calculations of time predictions broke down completely. The pendulum had a blot of imprecision. Like most systems, this high-precision machine had fallen into a chaotic pattern of locally unpredictable behavior.

In all fields of study, scientists struggled to make predictions with crate-loads of handwritten data and graphics, and often found themselves facing a dead end. No longer could they keep "smoothing over" irregularities. With the advent of the computer age, the "fudge" factor was becoming a less viable option. Scientists were confronted with the impracticality of inventing variables just to force a calculated result—feeling an urgency to explain the discrepancy between theory and experiment. In short, the dynamics of instability had to be recognized.

By the 1970s, a small circle of scientists in such fields as astrophysics, microbiology, chemistry, particle physics, meteorology, and botany came to realize that certain aspects of their disciplines defied predictions, patterns, and order. They came face to face with irregularities they could not explain, due mainly to the complexity of almost unending numbers of variables. And early on, some of the scientists, such as Mitchell Feigenbaum, a mathematical physicist at Los Alamos National Laboratory, realized that not only is randomness important to study, but that it is, perhaps, a factor that should be elevated to the status of a science. In the 1970s, he began mapping chaos, determined to unravel the seemingly intractable random behavior of chaotic systems.

For Feigenbaum, it started after playing with a cheap calculator. He sensed that something was flowing from the random numbers on his machine. They represented a rhythm, more than just pure mathematical units, perhaps something that embodied the fingerprints of God, but far too complex for human beings to understand. In a flash, he saw that chaos pervades every aspect of physical existence. With more study, he discovered from these rhythms that when orderly systems disorganized into chaos, patterns would develop. It was so precise that the pattern was defined by a number, 4.669, now known as the "Feigenbaum constant."

Feigenbaum was the first to formulate a mathematical constant to plot the cause of chaos. Eventually, other rhythms were discovered, and soon these causes became known as "strange attractors." When entered into computers as mathematical formulae, strange attractors would produce beautiful, colorful, and infinitely complex psychedelic images reminiscent of the Haight-Ashbury hippie days of the 1960s. They were christened "fractals."

With the advent of high-speed computers, scientists began to explore this new world. They were able to input data and perform previously impossible calculations. With this new tool, they could now plot complex systems. The world had entered THE CHAOS ZONE.

What Is Chaos, Anyhow?

So what exactly is chaos? It is not, obviously, a prerequisite to warfare, bloody riots, or crime-infested inner cities spiraling out of control. Such violent episodes are usually the backwashing effect of arbitrary controls imposed on society, or bitter turf battles between warring political factions. The Taoist philosopher who developed the concept of *yin* and *yang*, Lao Tsu, addressed this conundrum back in 600 B.C., writing: *Why are the people rebellious? Because the rulers interfere too much…Why do the people think so little of death? Because the rulers demand too much of life*."[4]

First and foremost, chaos is the engine of nonlinear change, an unfolding emergence, often with neither detailed blueprints nor mankind's permission. But, paradoxically, the theory of chaos is actually a theory about order and mathematical algorithms that encompasses unpredictable and complex systems.

One way to look at chaos theory is to consider the workings of a roulette wheel. The bouncing ball represents randomness and uncertainty, but the rest of the system is deterministic—stable structures composed of a solid, mahogany bowl, an aircraft-grade aluminum wheel, and chrome-plated ball pocket separators. Only the final destination of the roulette ball is unknown—the attractor. Some have attempted to measure the height from which the roulette ball is dropped, the speed of the spinning wheel, and the dimension of the table. In theory, if the numbers were plugged into a differential equation, the right answer should be easy to calculate. But it does not work that way; the measurements are too small to gauge, and there are too many other variables to allow for an accurate prediction—which together add up the exact recipe for chaotic systems.

Others have depicted "mathematical chaos" in more academic terms. In Stephen H. Kellert's book *In the Wake of Chaos*, he defines chaos theory as "the qualitative study of unstable aperiodic behavior in deterministic nonlinear dynamical systems."[5] Definitely a mouthful, but a better definition of chaos is difficult to pinpoint, for both scientists and laymen alike. In fact, some have referred to chaos as an unsolvable paradox in which chaos and order seem to be dissimilar and similar at the same time. Physicist Joseph Ford, in *The New Physics*, made this observation, referring to chaos as "a paradox hidden inside a puzzle shrouded by an enigma," which is, interestingly, paraphrased from Winston Churchill's description of a perplexing Russia.[6]

Chaos theorists primarily seek to understand the dynamics of change and how it relates to the universal behavior of complex systems. They research the types of changes that are unpredictable, erratic, and patternless, such as roiling fluids, turbulent clouds, irregular heartbeats, raging wildfires, market fluctuations, and confusing military battles—everything that traditional scientists avoid as being either too complex or unworthy of research.

And as traditional scientists have begun to reexamine these unexplained phenomena, they have found more puzzles in what some have referred to as "ordered chaos." For instance, in physics, "Why is it that simple particles obeying simple rules will sometimes engage in most astonishing, unpredictable behavior?" asks M. Mitchell Waldrop in *Complexity*.[7] Or why does order sometimes spontaneously arise from chaotic situations, and vice versa? Why does chaos erupt within seemingly perfect, ordered structures? What power, divinity, or even mindless intelligence is behind these processes—like the nebulous origins of the first galaxies? Or are we just observing chaos and order simply trying to reach some type of equilibrium—what chaos scientists call "the edge of chaos?"

Gleick takes a different approach, asserting that "to some physicists chaos is a science of process rather than state, of becoming rather than being."[8] Simply stated, chaos appears to be the instrument by which most changes occur.

Some partisans of chaology go a step further, contending that order comes from chaos, and chaos from order—a sort of cosmic yin and yang bound together by some unknown force, but repelled by another. Others have claimed that order and chaos have a symbiotic relationship, in which each needs the other to survive, as though they were negatively and positively charged particles, or matter and anti-matter. Or better yet, as with the Heisenberg's uncertainty principle of either particle-like or wave-like electrons, chaos and order are like "the man and woman in the weather house. If one comes out the other goes in." This description refers to the indecisive nature of subatomic particles—either wave-like or particle-like, but never both simultaneously. As more scientists scrutinized chaotic systems and complexity, it became apparent that the rules had changed. In fact, under the prism of chaos, the mere act of playing the game had a way of changing the rules. Except within narrow limits, predictability was now seen as an almost impossible feat. The comfort of feeling in control of one's own situation was no long assured.

Where Is the Control?

We all want control in our lives. But are controls and order available at our fingertips? Consider the scary implications of the meltdown in the reactor at Three Miles Island Nuclear Generating Station in Pennsylvania on March 28, 1979. The control room had over a thousand gauges, lights, and dials with which to monitor the reactor. Despite this massive array of instrumentation, and excellent safety and feedback systems, nobody really knew what was happening to the reactor, long after piercing horns and sirens had alerted the engineers.

Actually, nothing was wrong with the nuclear reactor. Workmen cleaning a minor filtering device had somehow set off the alarm. In typical chain-reaction mode, the system started to drain cooling water away from the nuclear core when a small valve failed to close. Although the core had overheated to 4,300 degrees Fahrenheit, conflicting information convinced the engineers to shut down the emergency water system—the worse possible reaction.

For two days, operators thought they had solved the problem, until shockingly, they detected radioactive gases inside the plant. They could not believe it. "We had a mindset that said we had these marvelous safety systems which had back-ups of back-ups," said Bob Long, a supervising engineer at Three Mile Island. "It was hard for people to really come to grips with the reality that severe damage had occurred."[9]

When the astronauts of America's Apollo 13 mission (April 11-17, 1970) arrived back on Earth, they were stunned to learn of the seemingly unrelated, minor events that had led to the oxygen tank explosion which had almost cost them their lives. Before going into space, the astronauts had been subjected by NASA's engineers to a series of mock problems, simulating improbable malfunctions. But none of the simulated malfunctions had come close to what occurred in flight. After learning what had crippled their spacecraft, the astronauts said that they would have refused to go on the voyage if they had known that such problems could actually happen.

Similar to the crisis fictionalized in Michael Crichton's *Jurassic Park*, almost unnoticeable and immeasurable events—called micro-events—can significantly affect the outcome of seemingly unrelated events. In the case of Three Mile Island, a series of minor mistakes increased the instability of a system that had been considered foolproof. The control room operators were in an automated, information-rich environment with many dials at their fingertips. And yet there was a meltdown in the information feedback loop and a misplaced confidence. As the runaway reactor veered out of control, the engineers leaned back in their control chairs and believed their information to be accurate and their emergency response methods successful. Like many, they believed that they had everything under control.

The Serenity of Order

One can glance up into a starry sky and feel a sense of peace and serenity, secure in the belief that tomorrow will be no different from today. In reality, no day is the same as another—a scientific impossibility. To some, it might appear that human beings are caught in boring routines—dragging their bodies to work, hauling out the trash cans weekly, and turning over their income tax paperwork to the IRS before the deadline. But such linear tranquility is misleading.

Order is not universal. In fact, many chaologists and physicists posit that universal laws are more flexible than first realized, and less rigid—operating in spurts, jumps, and leaps, instead of like clockwork. Chaos prevails over rules and systems because it has the freedom of infinite complexity over the known, unknown, and the unknowable. One best-selling science fiction author, Terry Pratchett, assigned a pejorative spin to stability, observing that, "Chaos is found in greatest abundance wherever order is being sought. Chaos always defeats order because it is better organized."[10]

But how rare is order? Complexity scientists often like to use the example of a deck of shuffled playing cards. Since gambling relies on a thorough, random shuffle, the cards are dealt in no special order. Four aces would be a good poker hand, potentially a winner, but the probability of this occurrence is quite slim. The odds of dealing four aces in a poker game are one in about 270,000 shuffles. Order has a low probability.

So what is order? Linguists might describe it as a methodical and systematic arrangement that organizes things in a geometrical or hierarchical way, biased toward uniformity or regularity. But according to the basic principles of ontology, any entity that exists cannot be identical to another entity. True uniformity is impossible. In fact, if the universe were based on pure order, it could not exist. It would be a closed, dead-end system, since change is a major constant of the universe. In short, without the interaction of chaos, there would be no creative process in which to create the universe. Literally, we owe our very existence to the interaction of chaotic conditions and complexity. Otherwise, we would all be floating in an entropic "heat death" of nothingness.

Self-Organizing Systems or Complex Adaptive Systems

As more physicists, mathematicians, and scientists have delved into nonlinear, dynamic systems, they have come up with one astounding conclusion: The universe appears to be guided by a set of fairly simple physical laws that can create amazing complexity. But despite this awe-inspiring complexity, they've found no specific blueprint or any predetermined system. Further, they have realized that not only are stable and predictable systems uncommon, but they are "incredibly scarce" in the universe. More exciting, they've found that chaotic and complex systems have enough adaptability to govern themselves better than do orderly ones commanded by external forces. Suddenly, a whole new subfield, complexity science, has arisen, dedicated to the understanding of "self-organizing systems," also known as "complex adaptive systems."

Complex adaptive systems are based on self-organizing systems that optimize their own functions. Considered autonomous, they have a natural and almost organic tendency for self-improving and self-organizing. John H. Holland, the originator of the "genetic algorithm" computer program, refers to this self-learning process as "the hidden order" in which stability emerges in everything from the indomitable drive of animal migration to the persistent hexagonal-shaped structure of every snowflake.[11] Many economists use the term "spontaneous order" to describe the self-organizing phenomenon in marketplaces, where stability is abundant. Biologists see "self-assembly" in biological and chemical systems, from the subcellular level to entire ecosystems. And still others, such as theoretical biologist Stuart Kauffman, point to "autocatalytic processes" and "autopoiesis" to explain the origins of life. In all these cases, a deeply hidden order emerges from inside an organism, not necessarily from outside forces.[12]

Naturally, the revelation that systems organize on their own sat poorly with the apostles of social sciences—especially political scientists who base their theories on imposing external controls to achieve selected political goals. They are accustomed to thinking about government-produced certainties, not ambiguous probabilities. In their linear calculations, humanity must be physically forced to follow the guiding light of political leaders or flavor-of-the-month ideologies. The economy and human actions must march in step with legislative or dictated law, no matter what the outcome. Yet natural systems do not operate this way.

Political systems are self-destructive constructs. They possess a de-evolutionary or cannibalizing nature, locked firmly within closed-ended structures, micromanaged from top tiers, and endowed with an overwhelming capacity to crank out external controls in assembly-line fashion. With clockwork precision, these systems manufacture rules and a legal apparatus which in turn erect artificial barriers to prevent the optimizing processes of evolution and information fluidity. Instead of embracing self-determination for subgroups, they live off the energy of all autonomous organisms within their territory. And if that resource becomes depleted, they go after those in other, neighboring lands.

Chaos theory and complexity science demonstrate that in a constantly evolving environment, individual agents require unfettered leeway to adapt. Without flexibility, the obstructive walls of regulations, taxes, edicts, laws, licenses, and so forth can only hamstring, starve, or destroy upstart organisms. In economics as well as in biology, this premise has been shown to be scientifically accurate. With mathematical modeling, physical chemist Ilya Prigogine proved that systems need to dissipate their energy to create new systems of higher order. He won a Nobel Prize for chemistry in 1977 for this discovery concerning "non-equilibrium thermodynamics." In *Order Out of Chaos*, Prigogine illustrated how open-ended systems (dynamic, far-from-equilibrium systems) will leap spontaneously into higher organization—challenging the "dead heat" of entropy, negating the certainty of determinism and confirming the irreversibility of time.[13] He argued that the dynamics of dissipation were necessary for self-organizing structures to work off the products of their instabilities. Not only did these "dissipative structures" resist entropy but they also expanded their energy output. Prigogine's research sent shock waves across the scientific community, because it contradicted certain aspects of entropy.

Evolution vs. Entropy

Evolution and entropy share a problem: they contradict each other. Entropy, according to the second law of thermodynamics, is the natural tendency of the universe toward disorder. The big machine of the universe is grinding down, leaking energy through energy sinks, as gears wear away gears, eventually reaching a nearly uniform absolute cold of deep-space emptiness. This process contradicts evolution, which states that lower forms give rise to increasingly higher levels of organization and complexity.

One of Prigogine's greatest achievements was to bridge the gap between natural science and social science. A number of experts have applied Prigogine's theories to the field of economics, arguing that command-and-control systems usually debase the economic lives of citizens. Such rigid structures embrace entropy, by artificially dissipating the energy of any autonomous system or subsystem that might challenge their authority. The imposition of government obtrusion obstructs the evolutionary and dynamic process that may lead to more complex organisms.

To illustrate this point, consider the case of an entrepreneur organizing a small company to sell hand-held police scanners or receivers in Belgium. These devices can monitor civil or military frequency ranges. The owner of the new enterprise might earn a living by selling the device to commuters who want to avoid heavy traffic resulting from accidents, natural disasters, terrorist attacks, or other emergencies. To initiate this microbusiness, the owner might purchase the scanners in bulk from Japan or Taiwan, open a small office, hire a salesperson or two, arrange for some accounting software, and vacuum the carpets at night. But the entrepreneur has one big obstacle: It is illegal to use police scanners in Belgium. There, as in much of Europe, most things are illegal until Parliament decides to legislate their legality.

In many nations, new start-ups must be bonded costing hundreds of thousands of dollars, must go through long permit and licensing application processes, and must endure laws that make it difficult and expensive to fire incompetent staff. And because of culture and laws, the ability to raise early-stage financing is daunting, if not impossible, for those without many resources. If the company fails, as 30 to 50 percent of start-ups do, the legal and financial penalties would be intimidating. The World Bank often charts such difficulties, reporting that it takes 152 days to start a business in Spain, but only five days in the United States. It can take up to 288 days to enforce a contract in England, 425 days in India, and 1,390 days in Italy.[14] Perhaps this explains why, in 1997, *The Economist* claimed that the informal, off-the-books economy in developed countries was growing at three times the rate of growth in the official economy.[15]

Surviving initial conditions is vital for emergence. There can be no kick-start for new systems when they are discouraged or outlawed. But political systems generally impose protective and dominating barriers to prevent upstarts from competing. Many small, seat-of-the-pants businesses with few resources—such as Apple Computer and the Disney Brothers Studio—would never have gotten the chance to establish a foothold in a static environment. What became the billion-dollar fast-food restaurant franchise Carl's Jr. was started in 1941 as a street-corner hotdog pushcart. Political systems inhibit evolution and adaptation; they are the worst example of energy-dissipating entropy in action.

Under Prigogine's theories, external controls are the death knell to newly born organisms. In his models, a sort of "instability bubble" develops under linear systems, blocking the means to dissipate energy. And if this bubble—called the "bifurcation point"—bursts, there are two stark possible consequences. The organism will either collapse back into disorder, or take a higher road of increased order. For instance, after the turbulent war for American independence, the new nation organized into an innovative system that instilled higher stability. If George Washington's Continental Army had been captured, the colonies might have fallen into an unstable political stew of discontent and conflict, until the end of European colonialism.

The Death of Determinism and Positivism

Cracks in the predominance of linear, deterministic systems had actually developed long before the age of computers and chaos theory. In the early twentieth century, a new breed of physicists pioneered the science of quantum particles. Albert Einstein's relativity and Werner Heisenberg's quantum mechanics challenged the very notion of matter and space as absolute entities. But it was Heisenberg's discoveries that put a stake through the heart of determinism and the philosophy of positivism, showing the complete unpredictability of the subatomic world under the uncertainty principle.

Writing about the microscopic world of electrons, Heisenberg wrote: "The more precisely the position is determined, the less precisely the momentum is known."[16] With these seemingly innocent words, Heisenberg inadvertently attacked the core premise of causality and determinism. Predictability was no longer completely tethered to causality. The philosophical implications were profound.

In the Copenhagen interpretation of quantum mechanics, Heisenberg and Niels Bohr argued that on the elementary physical level, the universe is a collection of probabilities, and that the universe does not exist in a deterministic form. Even if scientists were able to construct instruments to produce infinitely precise measurements, they would still be unable to predict the exact path of each subatomic particle. Einstein was so offended by this interpretation of a random cosmos that he famously remarked: "I cannot believe that God would choose to play dice with the universe." Whereas, Bohr retorted: "Einstein, don't tell God what to do."

The real deathblow to determinism came when scientists posed one simple question: How can the future be predicted if one cannot accurately measure the present? Predominant from the sixteenth to nineteenth centuries, determinism and positivism represented the old, classical physics of Isaac Newton, in which the material world was thought to be precise, knowable, and predetermined. Reinforced by the successes of the Industrial Age, positivists saw the universe as a gigantic, smoothly operating machine. The Newtonian mechanistic paradigm held that "the laws of nature completely specify the past and future down to the finest details," explains Heinz R. Pagels, an American physicist from the New York Academy of Science, in *Cosmic Code*.[17] He writes that classical physicists mistakenly believed that "the universe was like a perfect machine: once we knew the position of its parts at one instant, they would be forever specified."

Newton had envisioned a perfect world with mechanical precision, reflecting the belief in an all-knowing god who micromanaged nature to the nth degree. These early scientists were looking for certainty in a world that was anything but certain. The famous French mathematician Pierre-Simon Laplace (1749–1827) took the extreme position that if enough facts and figures were known, it was possible to forecast events ahead of time and to "retrodict" the past.[18]

Auguste Comte, the founder of nineteenth-century positivism, took this a step further. He wanted to use science-based sociology to create a superior state of civilization, seeking to reengineer mankind and force it to obey laws just as strict as the physical laws of motion and gravity. In this way, more evils could be eliminated in an effort to improve the human condition. John Stuart Mill referred to Comte's philosophy as "despotism of society over the individual."

But the chains of determinism and positivism were broken with the arrival of quantum mechanics in the 1920s. Although highly controversial, quantum mechanics was no flash in the pan. What Heisenberg and other physicists theorized did work extremely well in laboratory experiments. In essence, quantum mechanics proved that Newton's determinism of infinite precision had instead the consistency of a pinball machine and a roller derby wrapped into one. The world was not deterministic after all, but rather "indeterministic." Nobody knew it, but the seeds of chaos theory had been sown.

Quantum mechanics also provided scientific evidence that the material world is based mostly on randomness, and that probability can be established only as a statistical aspect of physical phenomena. The position and momentum of subatomic particles are just probabilistic descriptions of future trajectories. This is not to imply that predictable conditions are impossible. Scientists are capable of predicting the future of certain phenomena, within narrow limits, such as the timing of weather patterns, volcanic eruptions, and solar eclipses. For example, with modern sensory devices, seismologists were able to forecast a disastrous earthquake that hit the city of Haicheng in Northeast China in 1975. Four other quakes in China were also successfully predicted, giving hope that these natural disasters could now be predicted beforehand. This sense of conquering nature did not last long. On July 28, 1976, a magnitude 7.8 quake hit Tanqshan, China, without warning, despite the use of similar equipment and methods.

Any one person is unlikely to experience a catastrophic event throughout his life—on a probability basis. It is comforting to see the sun rise every morning, but even such a daily occurrence is not 100 percent guaranteed. Nothing is. Uncertainty is inherent, because of the constant flux between the two extremes of unstable and stable dynamics at the "edge of chaos"—a sort of tightrope walker's balancing act, in which systems flux back and forth in disequilibrium. This is a place where innovation nibbles at the current state of affairs, anarchy battles stagnation, complexity mingles with simplicity, and adaptation gives birth to spontaneous unknowns in a process where things evolve to evolve.

Chaotic conditions are a consequence of complexity. William of Ockham (c. 1288 – c. 1348), of Occam's Razor fame, showed he understood this problem when he told people to keep things simple and to refrain from making convoluted mountains out of nondescript molehills. He suggested that people should not create complex explanations for simple phenomena. His sage advice was: "Entities should not be multiplied unnecessarily." Even Aristotle had his own theory about cutting away complexity, writing that "the more perfect a nature is, the fewer means it requires for its operation."

The minimalist nature of simplicity often works well, because as a system becomes more complex, it behaves more unpredictably. Even worse, a complex system might break down at an utterly obscure single point of failure, requiring parts that are inaccessible or obsolete, along with the engineering skills to figure out what is wrong. It can be readily argued that success lies in the simplicity of the interactions among a system's components. As with heavy industrial equipment, the more moving parts, the more potential for breakdowns. As the old motherly saying goes, "Don't buy fancy cars with all of those fancy gizmos. They'll just break down and cause nothing but heartache." And it is true. Vehicles with more elaborate gadgets such as automatic headlights, rain-sensing wipers, power-heated memory mirrors, power moon roofs, and cruise control do malfunction at greater rates, simply because there is more to go wrong.

And yet in a paradoxical rub, the simplest of systems often present extraordinarily difficult problems of predictability—for example, calculating the direction and height of a bouncing ball. Scientists can predict the ball's movement, but only on a probability basis that may be far off the mark. The reason usually cited is that deterministic systems are so sensitive to measurements that their output appears random. Small effects can and do have spectacular or devastating outcomes, not only in weather but also in the economic and political realm.

Chaology and Economics

The field of economics is not exempt from the consequences of chaos and complexity. Marketplaces are indeterminate; value is subjective; and outcomes are subject to interpretation. Economic forecasting is just as nebulous, being based on the probability of statistical information that may or may not be accurate. As the comedian Jim Hightower once joked: "The amazing thing to me is that people who laugh at Gypsy fortune-tellers take economists seriously."

Despite the difficulty in understanding the complexity of markets and consumers, economics is often viewed as though it were something that could be physically touched, handcuffed by police, or made to sit down on command. Incredibly, individuals and companies making up markets are compelled to perform in ways that contradict the optimizing mechanics of greater choices and options. The business of trade becomes politicalized and centralized, measuring people and situations with one yardstick. Markets are put under a collective sword and commanded to achieve mandated goals that ignore aggregated choice. Under an increasingly global economy, each individual is an independent subsystem, a one-person agent acting on a wide variety of choices together with 6 billion other agents—making it impossible to understand much of the overlapping and jumbled complexity, except in broad, brush-stoke terms.

Take the example of how people spend their money. Why would anyone purchase a round, gray pebble in a box with printed instructions explaining how to care for a piece of granite? Yet in 1975, the originator of the Pet Rock, Gary Dahl, bought tons of Rosarito Beach stones for a penny a piece, and packed them in wood shavings inside a gift box modeled after a pet carrying case. Newsweek considered it a nutty craze, but Dahl sold enough rocks in a box to make him a millionaire.

In the 1980s, Ken Hakuta did something similar. He discovered a cheap, strange novelty item selling in Japan. It had no practical application, but with his import-export business, he decided to buy some for the United States market. The object looked like a small octopus. It was sticky and rubbery, and when it was thrown against a wall or window, it would slowly wobble down to the floor. He named it the Wacky WallWalker. Within a few months, his little toy became a wildly popular fad, selling over 250 million units and earning Hakuta over $20 million.

Tastes are truly subjective. From Hula Hoops to Lava Lamps, seemingly impractical consumer goods make innovators wealthy. Nobody has the ability to predict such outcomes. Economic indicators are clouded by a fickle public. As futurist Peter Schwartz wrote, "Information is always contaminated by people's beliefs and is never really complete."

Because information is often biased, outdated, or inadequate, command-based systems rely on obtuse information to produce blunt solutions. Wielding force like drunken revelers, political systems gamble on the singularity of direction to fix a multiplicity of problems, woefully ignorant that one size does not fit all. Blinded by political ideologies, they rarely act to solve underlying problems. Karl Hess (1923-1994), a former presidential speech writer, noted this condition, observing, "Politicians occasionally do the right thing—but only after they've exhausted all the alternatives."

A host of distortions are inevitable in command-based systems. When external controls are imposed on a complex system already built on prior consent, the integrity of its structure is jeopardized. Systems can be managed, but not entirely controlled, by outside forces. If these controls are mandated—as with the prohibition of alcohol in the United States—individual agents will actively sabotage the system, go underground, or circumvent the law.

This is not rocket science. Market chaologists understand that unintended consequences befall the best of intentions on a recurring basis. Nations struggle daily with unstable conditions, mostly because of past, misguided policies. Every system, public or private, has an inbred tendency to engender the exact opposite of intended goals. If an agency has a policy to uplift the impoverished, almost inevitably the outcome will be the downtrodden being mired in even greater poverty. This is exactly what occurred after President Lyndon Johnson launched his popular campaign of "total victory" for the "War on Poverty" in 1964.

On the surface, Johnson's programs appeared noble in their quest to eliminate economic hardship for the poor. But ever since Roman times, political systems have found it advantageous to play the bread-and-circuses game. The Johnson administration excelled at these festivities, concocting a massive welfare program to eliminate poverty once and for all. Johnson submitted, and Congress enacted, more than one hundred major proposals for his anti-poverty agenda. Of course, with aid to poverty now nationalized, long-established groups dedicated to assisting the poor—community groups, churches, charities, and nonprofits—were pushed to the back burner.

So what happened? After over forty years and $8.9 trillion spent, the poverty rate has remained steady.[19] According to the U.S. Census Bureau, the poverty rate in the United States was 12.1 percent in 1969. It jumped up and down, until it peaked at 15.2 percent in 1983. By 2004, it was at 12.7 percent. Poverty did not decline as promised: it actually increased. The only things that shrank were citizens' wallets, as tax rates ballooned to pay for unsuccessful social-engineering programs.

And how much government assistance did the poor get? According to Peter G. Peterson, Secretary of Commerce under President Nixon, in *From Running on Empty*, "In 2002, out of $1.2 trillion in federal, state and local benefits, the poor received roughly $140 billion, according to the Census Bureau. That's about 12 cents of every full benefit dollar."[20] Interestingly, most nonprofit charities spend 75 percent to 85 percent of their money on program activities. However, in 1965, before government's federalization of charity had started, "70 cents of every dollar spent by the government to fight poverty went directly to poor people."[21]

Not only did the poor get a small percentage of government funds earmarked to fight poverty, but according to Peterson, "social-welfare programs no longer redistribute wealth in favor of low-income households. Total federal benefits to the affluent are at least as substantial as those to the needy. Among Social Security beneficiaries, for instance, households with incomes of $150,000 or more received, on the average, checks that are twice as large as those of households with incomes of less than $15,000."[22]

But who actually pays the highest percentage of their wages in taxes? It turns out that in California, the poorest of the poor bear the highest tax burden. But California is often cited as having done more than most states to address tax fairness. Still, according to the Matthew Gardner, executive director of the nonpartisan Institute on Taxation and Economic Policy in Washington, D.C., many states, including California, have a regressive "upside-down tax system. The more you earn, the less you pay in taxes." The California Budget Project agreed, asserting that "the poorest fifth of taxpayers in California pay 11.7 percent of their annual income for state and local taxes, which include income, sales, and excise taxes. In contrast, the richest 1 percent of taxpayers fork over 7.1 percent of their income. In the case of middle-income earners, they pay 9.5 percent of their income.[23]

Nor did government-operated education fare any better. Literacy rates were higher in 1840 than they are in 2011, despite the fact that government schooling systems were almost nonexistent for the first hundred years of United States history. Between 1800 and 1840, literacy in the Northern United States increased from 75 percent to 90 percent, and in the Southern from 60 percent to 81 percent, according to Sheldon Richman in *Separating School and State*.[24] In fact, by 1850, Massachusetts had a literacy rate of 98 percent. John Adams once observed that it was easier to locate a comet in the sky than to find an uneducated man in America.

But in 2011, not only have literacy rates plunged, but a high percentage of public school teachers fail to pass basic skills and subject matter tests that are often required for employment. "In Virginia, nearly one-third of aspiring teachers did not pass the Praxis test of basic skills in reading, writing, and math" in 1998.[25] Also in 1998, approximately 1,800 would-be teachers in Massachusetts took a first-ever high school level teacher's test. The failure rate was 59 percent. Equally stunning is the fact that the cities found doling out the most money per student—Washington, D.C., and New York City—produce the lowest scholastic results per graduating student, ranking near the bottom on almost every level of performance. The results from government-managed education have almost become a mathematical constant—the more money spent, the worse the performance.

Voted by the New York State Education Department as New York State Teacher of the Year in 1991, John Gatto points out in *The Underground History of American Education* that literacy rates have plunged in America since the 1930s. His example is the fourth-grade reading test given to U.S. military draftees. During World War II, 96 percent of draftees passed the simple test; 81 percent passed during the Korean War, and only 73 percent during the Vietnam Conflict.

In 1993, the National Adult Literacy Survey determined that only 3.5 percent of the American adult population were capable of literary skill adequate for traditional college study, compared to 30 percent in 1940.

The education establishment is repeatedly confounded when it is revealed that college graduates' reading proficiency continues to decline. "It's appalling—it's really astounding," said Michael Gorman, president of the American Library Association. "Only 31 percent of college graduates can read a complex book and extrapolate from it. That's not saying much for the remainder." Back in 1992, that figure was 40 percent of college graduates.[26]

A more ominous sign is the cheating scandal uncovered in 2011 in Atlanta, Georgia, where 178 public school teachers and principals were caught in a widespread scheme to cheat on the state-mandated Criterion-Referenced Competency Test.[27] The 800-page investigative report discovered that the cheating was systematic and was occurring in close to 80 percent of the schools examined. In many cases, teachers admitted to being intimidated or forced to help students cheat on the standardized tests. The report stated that "a culture of fear, intimidation and retaliation existed in Atlanta Public Schools, which created a conspiracy of silence." In one instance, "a principal forced a teacher to crawl under a table during a faculty meeting because that teacher's [students'] test scores were low."[28]

Superintendent Dr. Beverly L. Hall, who had been named the 2009 National Superintendent of the Year, became the center of the cheating scandal. According to the New York Times, "Dr. Hall's administration punished whistle-blowers, hid or manipulated information and illegally altered documents related to the tests, the investigation found."[29]

Even comedian Jay Leno took a dig at the scandal, joking: "You know who gets hurt by something like this? The kids. The kids are the ones who get hurt, because they're never going to learn how to cheat on their own."[30]

As government continues to intervene in education, the system loses its adaptive quality. It can no longer remain an independent structure of education, but becomes rather a systematic entrenchment of the political status quo, destined to fail at educating. Command-based systems inevitably collapse into unintended consequences of disastrous proportions. One of the biggest reasons for this is the problem of predictability.

Predictability—The Future Leaves No Footprints

Political theory would be fine in a perfect world, but in an uncertain one, it is a dangerous gamble. As historian William Durant wrote, "Inquiry is fatal to certainty."

The inquiring eye of science has demonstrated that long-term predictability is nearly nonexistent. One of the main obstacles to predicting the future is that information comes in extremes—either too much or too little. There is little middle ground.

Obviously, making predictions is difficult when information is not available. But the lack of accurate and meaningful information is not the only obstacle. It is a lack of perception of what the information should and can be. Often, one does not know what one does not know. Albert Einstein voiced this concern, and considered that the theories of physical reality extend further than observable events, although his theory of relativity is observer-centric.

In his conversation with Heisenberg in 1926, Einstein contended: "It is the theory which decides what can be observed."[31] In a sense, this statement is correct. Without knowing what to look for, how could anyone find what is not currently observable? To be able to predict, one must have some knowledge about what can be predicted. But uncertainty means that things could happen that are completely below the radar screen that occur in a way that nobody, in their wildest dreams, could have guessed. The problem has always been, not what *is* there, easily identified, but what is *not* readily observable. This is what makes predictability extremely unreliable. Ironically, it was his private conversation with Einstein that helped Heisenberg come up with certain aspects of his uncertainty principle.

The other extreme is just as problematic. Information overload can also lead to a paralysis in which nobody is certain of anything, because of mountains of often contradictory data. Stacks of papers published in fine print mix poorly with busy schedules and timetables. But this is the exact condition that legislators must endure on city, county, state, and federal levels. They are inundated with hundreds of pages of proposals, codes, and regulations on a daily or weekly basis. They rarely have the opportunity or patience to read and consider each and every page to glean potential consequences. In fact, most never read the bills that come across their desks. Instead, an overworked staff is responsible for analyzing piled-high volumes of nearly indecipherable bills and budget items. However, their primary duty is not to decipher future consequences to solve economic and societal problems, but rather to protect the political aspirations of their boss and to provide for their own job security.

In 2001, Congress passed the U.S.A. PATRIOT Act in response to the September 11 terrorist attacks. According to Congressman Ron Paul of Texas, the final revisions of this act that came out of the U.S. Senate were unavailable. He desperately tried to locate a copy. Congress would not wait, and instead voted for this bill without having seen the final version. In fact, Rep. Paul has disclosed that several Congressional colleagues told him personally that they believed the bill to be dangerous to civil liberties, and that they opposed it. And yet, they voted in favor of it, sight unseen, fearful of what their constituents might do, back home.

In some cases, bills are voted into law even before they have been written. During the 2009 budget meltdown in California, State Senator Abel Maldonado freely admitted, "We need to stop passing bills and budgets that aren't even written. We frequently vote on budgets in 'draft form,' meaning the language has not been finished."[32]

In 2010, U.S. Speaker of the House Nancy Pelosi, in a bout of honesty during debate over President Barack Obama's healthcare reform bill said, "We have to pass the bill so that you can find out what is in it, away from the fog of the controversy." With blindfolds tightly affixed, most lawmakers don't have the faintest idea what a bill actually says or what it will do.

As if that were not enough, Pelosi had proposed and seriously considered using the "deem and pass" tactic on that bill, which would have allowed it to become law without any Congressman actually having cast a vote. This gambit was not used after all for the passage of "ObamaCare," but many politicians argued that both parties had been guilty of this sort of political maneuvering in the past. The point now becomes obvious. What is the purpose of a legislative branch? If legislators don't read bills, write them, or vote for them, how can elected officials be considered representatives of the people?

Even when legislators are determined to do what is right, they are confronted by a wall of self-contradictory data and unpredictable consequences. And they are unlikely to make heads or tails out of economic trends, statistics, or changes. Political systems are primarily based on acquiring the reins of power, not on understanding the daily or long-term economic interactions of citizens. Pandering to voters counts more than sensible legislation; re-election money adds up more than the laws of supply and demand; and political expediency is more important than economic data. In the end, even those in the political landscape realize that nobody can declare precisely what effect a particular law will have in the future. Nonetheless, they toe the official party line and hope for economic conditions to favor the political party currently in the driver's seat. They know they are groping in the dark like everyone else. They know that the future leaves no footprints.

This lack of predictability is one of the major reasons that enacted laws have a high probability of resulting in the exact opposite of what the instigators had intended—a dynamic phenomenon called the "boomerang effect," sometimes referred to as the law of unintended consequences. Interestingly, the CIA coined their own word to refer to bad results from covert operations: blowback.

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The emergence of chaology is just the beginning of a new age of discovery. The knowledge gleaned from this new science will expand our understanding of how we think about science, society, and the clusters of individual parts that make up our world. Chaology will touch every field of study and eventually will redefine life and society, providing empowerment, connectivity, and self-governance.

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